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Students' Concept Mastery in Plant Physiology Course Using Learning Cycle Multiple Representation Model

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ABSTRACT

One of the essential goals of science learning is to lead students to master scientific concepts or ideas and apply them to explain relevant everyday phenomena. Such mastery should help students to work with various representations. The objective of this study was to determine the effectiveness of the Learning Cycle Multiple Representation (LCMR) model in students' mastery of concepts in plant physiology. This research was done using a quasi-experimental pretest-posttest design involving 62 students as the respondents. The concept mastery instrument consisted of 11 essay tests. The instrument met the value of validity and reliability. The data analysis was done using the one-way analysis of covariant set at a significance level of 5%. The results show that the LCMR model significantly affected students' mastery levels. The students who learned using the LCMR model showed significantly better mastery of the tested concept than the ones who used the LC model. The mastery score for the student learned using the LCMR model was 80.67, significantly higher ($p=0.00 <\alpha$) than that obtained from the LC model of 54.00. Apart from enhancing mastery in plant physiology, the LCMR method can be expanded for other topics, and its effectiveness can be evaluated in future studies.

Keywords: Mastery of concepts, Plant physiology, Learning Cycle, Multiple Representation

INTRODUCTION

One of the essential goals of science learning is to lead students to master the concepts or central ideas of science and apply them to explain relevant, everyday phenomena (Akın et al., 2015; Kolb & Kolb, 2017). Another important goal in science learning is that students can work with various representations (T. R. Anderson et al., 2013; Hahamy et al., 2017; Sunyono & Meristin, 2018). Recently, science educators acknowledged the importance of prospective educators in mastering science concepts (D'Alessio et al., 2019; Dring, 2019). Mastery of concepts in a field of science includes a combination of in-depth knowledge and dimensions of cognitive processes, including factual, conceptual, and procedural knowledge (Krathwohl, 2002). Students cannot be said to teach mastery if they only memorize the facts and concepts learned (Abdullah & Shariff, 2008; Zubaidah et al., 2018). A person is said to have mastered the concept if he/she can integrate the knowledge into higher-order thinking processes (L. W. Anderson et al., 2001; Krathwohl, 2002). Plant Physiology is a botany branch that studies plant survival activities (Hopkins & Hüner, 2008). Plant physiology also

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describes the various functions of plants in the plant life cycle (Taíz & Zeiger, 2010). Mastery of plant physiology is vital to understand the responsive behaviors of plants to the environment. In turn, prospective teachers also have strong enough provisions to guide their students when they become teachers. The plant physiology topics are rich with various representations, such as pictures, graphics, symbols, and verbal descriptions (N. A. Campbell & Jane B. Reece, 2012). Therefore, to master the plant physiology concept, students need to improve their ability to work with various representations. Based on this notion, students are expected to increase their mastery of the concepts through plant physiology learning.

Mastery of concepts in a field of science includes a combination of in-depth knowledge and dimensions of cognitive processes, including factual, conceptual, and procedural knowledge (Krathwohl, 2002). Students cannot be said to teach mastery if they only memorize the facts and concepts learned (Abdullah & Shariff, 2008; Zubaidah et al., 2018). A person is said to have mastered the concept if he/she can integrate the knowledge into higher-order thinking processes (L. W. Anderson et al., 2001; Krathwohl, 2002).

One factor that determines the success of learning is the mastery of the concepts by the teachers and/or the prospective teachers. Previous research has revealed that problems are still related to mastering the concept of future biology teachers in Indonesia (Amin et al., 2016). Regarding the field of Plant Physiology, preliminary research results revealed a low mastery of the concept. An assessment of 37 students who had taken the Plant Physiology course revealed that the average concept mastery was 31.35%. The test included three thinking indicators: analyzing, evaluating, and creating. Many learning models have been developed to enhance the student's mastery of a science concept.

The learning cycle framework or Learning cycle 5E has been evaluated to enhance concept mastery. Learning cycle 5E is one of the constructive learning models widely used. The learning stages consist of Engagement, Exploration, Explanation, Elaboration, and Evaluation (Namgyel & Bharaphan, 2017). Some of the advantages of LC 5E are as follows: helping lecturers in providing good learning instructions to students (Duran & Duran, 2004; Ihejiamaizu et al., 2018), improving the quality of science practice and learning based on structural approaches and cognitive psychology (Bybee et al., 2006; Seven et al., 2017), train students' critical thinking skills (Dring, 2019), guide students to learn science concepts, correcting incorrect or incomplete knowledge (Özbek et al., 2012; Tonseenon, 2017), facilitate inquiry learning in the classroom (Bıyıklı & Yagcı, 2015; M. Campbell, 2006), and improve scientific attitude (Faizin et al., 2018).

Multi-representation (MR) learning is done by re-representing information or objects into other forms of representation without removing the initial information from the object (Treagust & Tsui, 2013). Multi-representation needs to be designed in learning so that students have various skills to convey information (Sunyono et al., 2015). Students build mastery of science concepts in MR by adopting the role of representation to grow interested in learning: to interpret, discover, claim, process and create knowledge (Prain & Tytler, 2012). Therefore, the MR strategy can help students understand concepts by accommodating each representation's advantages and disadvantages. MR can support learning in many different ways (Ainsworth, 1999).

The MR framework refers to the IF-SO framework (Carolan et al., 2008). The I/Identify and F/Focus activities prepare lecturers before learning. In identify, the lecturer describes the key concepts or big ideas of a topic in the planning stage to anticipate the representation that will be built in developing their understanding and is considered as evidence of learning. In focus, lecturers focus on the form and function of various representations. Lecturers and students must learn the function and purpose of working with new representations.

Furthermore, lecturers and students play a role in learning by improving representation during the learning process (S/Sequence and O/Ongoing assessment). In a sequence (S), there needs to be a sequence of representations that generate student ideas, provide opportunities for them to explain their ideas, explore ideas in new situations, and relate representations to one another. In ongoing assessment (O), the lecturer examines the results of student representation as evidence that students think and learn.

Learning using MR has many benefits for students. Ainsworth (2008)interacting with multiple forms of representation such as diagrams, graphs and equations can bring unique benefits. Unfortunately, there is considerable evidence to show that learners ofte

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The LC model has characteristics (Snajdr, 2011) in which the lecturer provides students flexibility in each learning phase. The flexibility of the LC offers an opportunity to juxtapose it with the MR. In the exploration, explanation, and elaboration phases, the lecturer can provide activities or procedures for students to follow (Bell & Odom, 2012). Students can manipulate material, collect and organize data from investigation results with various representations in the exploration, explanation, and elaboration phases. The insertion of MR into the stages of LC learning is called Learning Cycle Multiple Representation (LCMR).

The LCMR model consists of engagement, where the lecturer provokes students' initial knowledge by asking questions related to the learning materials. The exploration phase provides students with investigative activities in small groups. In this activity, students can make structured representations to stimulate thinking processes. In the explanation phase, the lecturer directs students to explain concepts and demonstrate their skills in solving challenges in compiling representations. In the elaboration phase, the lecturer presents students with higher-order thinking activities to create depth and breadth of knowledge and connect ideas across topics. The evaluation phase is where the lecturer assesses student progress (Reinburg et al., 2018). In these three stages (exploration, explanation, and elaboration), students are trained to improve their mastery of concepts. This study aims to compare the effectiveness of LCMR and LC models in enhancing the mastery of a scientific concept in plant physiology. This research brings novelty in combining LC and MR to become LCMR in measuring students' mastery of concepts. To out best knowledge, such method is reported for the first time for teaching and learning of plant physiology material.

METHOD

Research Design

This research used the quasi-experimental pretest-posttest design. The treatment consisted of 2 types of learning, namely the LCMR model and the LC model. The dependent variable was the mastery of the concept.

Participants

The subjects in this study were 62 students in the 6th semester of the Biology Education Program. The research was conducted in the March-August semester of the 2019/2020 academic year. The equivalence test between classes was carried out using the student's cumulative GPA in semester 3. After obtaining the equivalence results, the experimental and control classes were randomly selected. The group of students in the experimental class underwent the study through the LCMR model, while the control class used the LC model. The learning steps are presented in Table 1.

Table 1: The learning steps in The LCMR and LC Models

Learning Cycle Multiple Representation (LCMR)	*Learning Cycle (LC)*
Engagement The lecturer introduced the Student Worksheet, the model used and provoked students' curiosity by asking questions related to the learning material.	*Engagement* It was the same as in the LCMR.
Exploration Students carried out investigative activities and arranged representations in small groups. S (Sequence): Students made representations through systematic stages. S I: Students created representation ideas that were later compiled by considering their pros and cons. S II: Students created representations by paying attention to interests, values, and aesthetic preferences.	*Exploration* Students carried out investigative activities as a learning experience to take a deeper look at the previously introduced topics. Students worked independently in small groups, resulting in experiential learning about topics and skills in the real world. Lecturers could direct students to compile the investigation results using MR to build concepts and skills based on experience.

Learning Cycle Multiple Representation (LCMR)	*Learning Cycle (LC)*
Explanation Lecturers directed students to explain the representations they made to strengthen the concepts and representation skills required in completing assignments. S III: Students provide perceptions to make connections between their representations.	*Explanation* Lecturers directed students to explain the concepts and skills required to solve challenges. Students carried out activities to demonstrate their understanding of the concepts and skills.
Elaboration Lecturers invited students to think at higher levels to create in-depth and breadth knowledge while connecting ideas across topics. O (Ongoing Assessment): The lecturer examined the representation outcomes as evidence of the thinking process. O I: students negotiated with lecturers regarding the assessment of their representation on whether their ideas were adequate about the topic and features of the object and on the extent of the goal of representation. O II: students clarified the parts and purposes of the various representations they had compiled on time.	*Elaboration* Lecturers invited students to think at higher levels to create in-depth and breadth knowledge while connecting ideas across topics. Students applied what they have learned in the Worksheet to new situations or described what they have learned about the studied material.
Evaluation Lecturers assessed student progress.	*Evaluation* It was the same as in the LCMR.
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Learning Cycle Multiple Representation (LCMR)	*Learning Cycle (LC)*
Evaluation	*Evaluation*
Lecturers assessed student progress.	It was the same as in the LCMR.

Data Collection Tools

The instrument for concept mastery refers to the revised Bloom's taxonomy (L. W. Anderson & Krathwohl, 2001), using C4-6: analyzing, evaluating, and creating. The eleven questions used have been assessed by two experts: a professor in the field of Biology education and a PhD holder in educational technology. The expert assessment was done on the material, rubric, assessment, and the use of language. The result of the expert assessment was 4.27, which fell under the valid category.

The validation process was carried out by giving a concept mastery test to 32 students in the 6th and 8th semesters who had taken the plant physiology courses. Students who took the 2 ×45 mins test had been informed that they would be tested. Two experts carried out the process of assessing test results using the inter-rater method for each question. The validity test results showed a strong correlation between the items on the total score with a range between 0.36-0.65 with a reasonably valid category, which is in line with a previous report (Creswell, 2012). Furthermore, the reliability test using Cohen's Kappa resulted in coefficient values of 0.43-0.68 fell under a good category.

The scoring rubric employed the one developed by Sutopo & Waldrip (2014), which was adapted from Furtak *et al.* (2010), and consisted of 0-4 levels of categorization of mastery of concepts (Table 2). The use of the assessment rubric was done involving two assessors. The concept mastery score was then converted to a value using Equation 1.

$$\text{Concept Mastery Value} = \frac{\text{Score obtained}}{\text{Total Score}} \text{ X } 100 \quad \text{...(1)}$$

Table 2: Concept Mastery Scoring Rubric

Category	*Score*	*Description*
Inductive/Deductive rule-based thinking	4	Correct answers are supplemented by reasons derived from comprehensive data analysis supported by principles, theories, laws, or definitions relevant to the data, and the problem is solved.
Evidence-based thinking	3	The reason has considered some data (including implicit data) and applied relevant data analysis, but it is not enough to solve the problem correctly.
Data based thinking	2	The reasons depend on limited data or incomplete features of the issue.
No reason	1	There is a reason, but it is only a claim or unrelated to the problem.
Unknown	0	The student answer sheet is blank

Data Analysis

The data analysis was done through the following steps. Firstly, the normality test using Kolmogorof Smirnov was conducted. Next, the homogeneity test was done using Levene's Test set with a significance level of 0.05. The concept mastery data was further analyzed using the one-way analysis of covariance (ANCOVA) test with a significance level of 0.05.

FINDINGS

The results of the concept mastery are presented in Table 3, showing an increasing score from the pretest to the posttest. The boxplots of all groups are shown in Figure 1. It clearly shows score improvement from the pre- to the post-tests.

The normality and homogeneity tests of the data were carried out on the pretest and posttest scores to know the data distribution. The results are summarized in Table 4.

Table 3: The Student Concept Mastery Results After Study Using The LCMR and LC Models.

		Mean	
Learning model	*N*	*Pretest*	*Posttest*
LCMR	30	41.69	80.67
LC	32	28.70	54.44

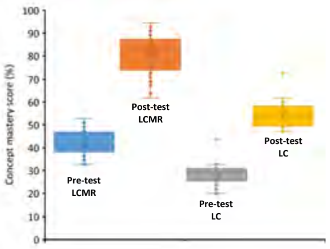


Fig. 1: Boxplots of concept mastery score of pre- and post-test of students' learning using for students Learning Cycle Multiple Representation (LCMR) and Learning Cycle (LC) models.

Table 4: Test for Normality and Homogeneity of Data

		Normality			*Homogeneity*			
Concept Mastery	*N*	*Mean*	*Kolmogorov Smirnov*	*Sig.*	*F*	*Df1*	*Df2*	*Sig.*
Pretest	62	34.99	0.95	0.33	1.65	3	58	0.19
Posttest	62	67.13	1.31	0.07	1.68	3	58	0.18

Table 5." Summary of Ancova Test Results for Concept Mastery Variable

Source	*Type III Sum of Squares*	*df*	*Mean square*	*F*	*Sig.*	*Partial Eta Squared*
Corrected model	11907.996a	2	5953.998	184.334	0.000	0.862
Intercept	2079.021	1	2079.021	64.366	0.000	0.522
Pretest Concept	1250.730	1	1250.730	38.722	0.000	0.396
Model	1498.378	1	1498.378	46.389	0.000	0.440
Error	1905.703	59	32.300			
Total	293181.908	62				
Corrected Total	13813.699	61				

R Squared = 0,862 (Adjusted R Squared = 0,857)

It was found that the significant value in the pretest and posttest was greater than the alpha value of 0.05 (p>α), implying that the pretest and posttest data were normally distributed.

The homogeneity test of the data related to the dependent variable was carried out using Levene's Test (Table 4). The significance value on the pretest and posttest is greater than the alpha value of 0.05 (p>α), implying that the pretest and posttest data had homogeneous variants. Based on the assumption test, the data met the prerequisites for the theoretical analysis of ANCOVA.

The results in Table 5 show a significant influence (p=0.00 <α) of the learning model on students' mastery of concepts. The LCMR model was significantly better than the LC model. The average concept mastery in the LCMR model was 80.67, much higher than the LC model of 54.44. Therefore, the LCMR model was proven effective in improving students' mastery of concepts in the Plant Physiology course.

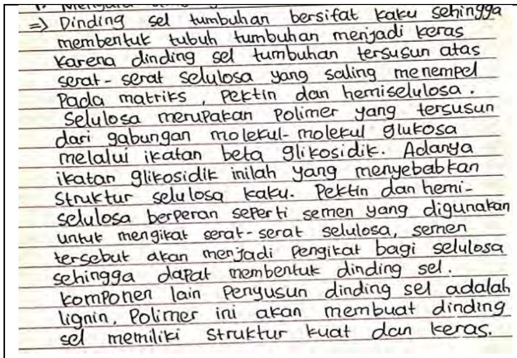
DISCUSSION

Mastering concepts is the primary basis of knowledge to create, explain, revise, analyze and evaluate ideas (Taşlıdere, 2013). Mastery of concepts requires educators to assist the students in mastering the taught concepts explicitly contained in learning (Tsui & Treagust, 2013). Educators can deliberately try to create disequilibrium through questions or student responses to direct them to think deeply and to express their ideas when forming conceptions (Chang, 2010).

The translation process is essential for understanding biological concepts (Schönborn & Bögeholz, 2009). A plausible concept must be believable and understood by the learner. Mastery is achieved from the accommodation of old and new concepts resulting in a conceptual exchange (Treagust & Tsui, 2013). Various ways have been done to deepen the mastery of concepts in science. Among them is guiding students in activities that provide opportunities to experience the construction (Hubber et al., 2010).

The LCMR model is proven to be better at understanding student concepts than the LC model, as demonstrated by the results of this study. The finding is somewhat anticipated considering that the LCMR model consisted of both the LC and the MR models that complement each other. The learning process guided students through structured and repetitive activities like a cycle. This cyclical learning pattern helped the students to quickly memorize the activities for one semester (Ihejiamaizu et al., 2018; Yaman & Karaşah, 2018). Then, in the LC stage, namely exploration, explanation, and elaboration, students were invited to use various representations. For example, for the learning materials on hypogeal and epigeal germination patterns. The students practiced well in presenting the germination pattern with diagrams, pictures, tables, and verbal explanations. Besides being able to improve their representational abilities, these activities were effective in enhancing their mastery of concepts. Therefore, the learning stages in LCMR supported students in understanding the material better than in the standalone LC model.

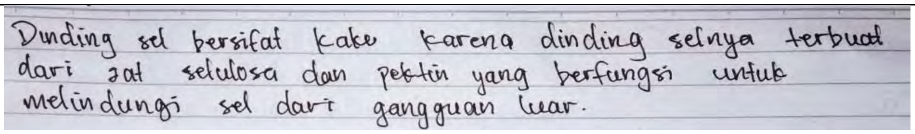
Examples of differences in student concept mastery based on the learning model used can be seen from the answers given when taking the posttest, presented in Figure 2. The questions used were "*Why are cell walls rigid? Tell!*"



=> Dinding sel tumbuhan bersifat kaku sehingga
membentuk tubuh tumbuhan menjadi keras
karena dinding sel tumbuhan tersusun atas
serat-serat selulosa yang saling menempel
pada matriks, pektin dan hemiselulosa.
Selulosa merupakan polimer yang tersusun
dari gabungan molekul-molekul glukosa
melalui ikatan beta glikosidik. Adanya
ikatan glikosidik inilah yang menyebabkan
struktur selulosa kaku. Pektin dan hemi-
selulosa berperan seperti semen yang digunakan
untuk mengikat serat-serat selulosa, semen
tersebut akan menjadi pengikat bagi selulosa
sehingga dapat membentuk dinding sel.
komponen lain penyusun dinding sel adalah
lignin, polimer ini akan membuat dinding
sel memiliki struktur kuat dan keras.

Answer: Plant cell walls are rigid, forming a hard plant body. It is because plant cell walls are composed of cellulose fibers attached to a matrix, pectin, and hemicellulose. Cellulose is a polymer consisting of glucose molecules combined through beta-glycosidic bonds. The presence of glycosidic bonds resulted in a rigid cellulose structure. Pectin and hemicellulose act like cement that binds cellulose fibers forming the cell walls. Another component that makes up a cell is lignin. It turns the cell wall stronger with a rigid structure.

(a)



Dinding sel bersifat kaku karena dinding selnya terbuat
dari zat selulosa dan pektin yang berfungsi untuk
melindungi sel dari gangguan luar.

Answer: The cell wall is rigid because it is made of cellulose and pectin substances which function to protect cells from outside disturbances.

(b)

Fig. 2: Examples of Student Answers for Concept Mastery Tests: (a) Using the LCMR Model, (b) Using the LC Model

Figure 2a is the student's answer after undergoing the LCMR learning process. Figure 2b is the student's answer from the LC model. Both figures show a clear difference in the pattern of responses. Students who learned through the LCMR model demonstrated a mastery of concepts. The student could explain the causes of rigid cell walls by providing reasons for the structure of the cell wall, the organelles in the constituent cell wall, the chemical compounds contained in the cell wall, and the function of each of these chemical compounds, developing a logical construction. Meanwhile, the student that learnt through the LC model only briefly mentioned the cell wall components without describing the reasons for the answers.

The ability of students to explain science concepts is also influenced by the learning environment they go through (Weay & Masood, 2015). The learning environment refers to the learning model used (Malik & Ubaidillah, 2020). The LCMR learning model consists of the LC 5E and MR models, which are constructivist. Students' knowledge is built through prior knowledge and then guided using the LC model that provides exercises in composing various representations. Students are facilitated to master science concepts well when using a suitable learning model (L. W. Anderson et al., 2001). It is because MR learning can help students interpret one representation and make connections between representations (Rau & Matthews, 2017).

The LCMR learning model positively influences students' mastery of concepts in Plant Physiology material, as proven by the results of this study. The results illustrate that students' mastery of concepts is better in implementing the LCMR model than the LC model. It can further be explained by the characteristics of the LCMR model syntax. It consists of 5 stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation. In the exploration, explanation, and elaboration stages, an MR strategy is inserted so that learning becomes more of a practice of compiling representations and growing concept mastery.

The following describes the learning activities at each stage of the LCMR model. The initial stage was forming groups of 3 students with heterogeneous backgrounds, after which they entered the engagement stage. At the engagement stage, students identified some key concepts. Lecturers then guided students to identify key concepts or essential ideas. Social interaction in the form of collaborative groups played an important role in forming cognition that could increase students' mastery of concepts (Kong, 2012; Nitjarunkul, 2015; Noviyanti et al., 2019)SMAN 3 Malang and SMAN 7 Malang. The first served as the representative of students with high academic ability and the latter was appointed to represent the low achievers. The data were analyzed using an independent-samples t-test. The results showed that there were significant differences between the high and ability students' scientific argumentation skills with a p-value of 0.003. Around 10.34% of the high achievers could perform level 1 argumentation skills, 74.41% of them were able to achieve level 2, and 17.24% of the students reported level 3

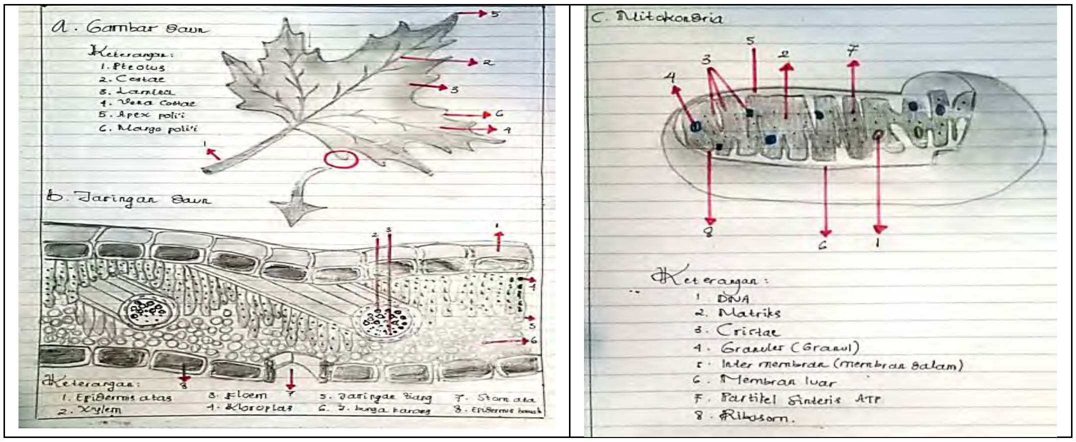


Fig. 3: The answer of a student after learning using the LCMR model. (a) shows a picture of a leaf and its description. (b) depicts an illustration of an enlarged leaf to display an image of the tissue with its parts, namely the upper epidermis, xylem, phloem, chloroplasts, pole tissue, spongy tissue, stomata, and epidermis. Furthermore, (c) depicts the mitochondrial part of the leaf tissue drawn by showing its features, namely DNA, matrix, crystal, granular, outer membrane, inner membrane, protein synthesis particles, and ribosomes.J

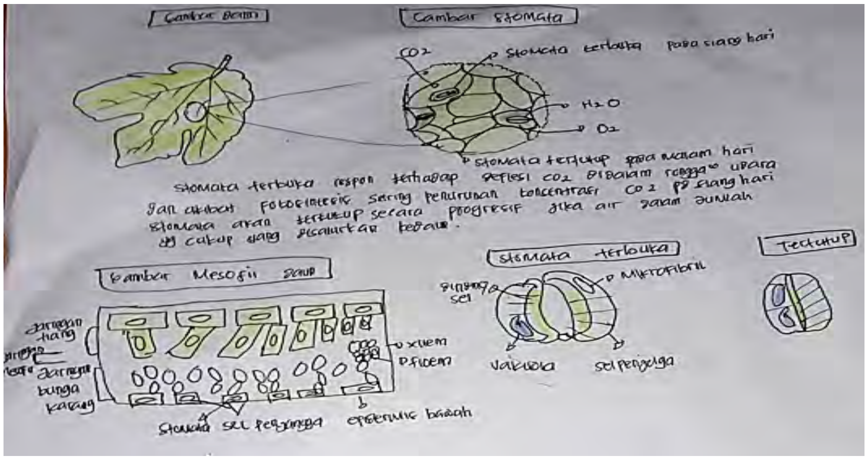
responses. Among the students with low academic ability, 12% had reached level 1 argumentation skills and 88% of them were only able to achieve level 2, indicating that no one (0%.

Next, the exploration stage focused on compiling the form and function of MR. At this stage, students were led to make representations using the Worksheets that had been previously distributed. Lecturers and students determined the type of representation to be compiled and then studied the function and purpose of the prepared representation. For example, students should be asked to consider why they were used in working with graphs. This way, lecturers could guide students to learn about the types of representations and their purpose in using them as a medium to explain natural phenomena, as discussed elsewhere (Sutopo, 2013). They must be challenged and supported in coordinating representations as a means of coherent, defensible and flexible understanding of expression (Waldrip et al., 2010).

The explanation stage is where students and lecturers confirm their mutual perceptions about the form of the prepared representations. Students, through group representatives, presented their work, and then the lecturer provided input or suggestions to complete or improve their work. Next, in the elaboration stage, students explained the form of the prepared representation through a simple presentation. Students recorded their presentation activities. Then the recording file was sent to the lecturer. The last stage was the evaluation, where the lecturer provided tests to students. The tests were tailored to the learning objectives and provided library analysis tasks related to the following study materials.

The effectiveness of the LCMR model in enhancing concept mastery was because the concept was studied accurately, structured, and meaningfully (Quitadamo & Kurtz, 1993). The learning process supported the creation of a learning atmosphere that trained the thinking process (Husni et al., 2019; Koedinger et al., 2012). Through mastery of concepts, students learned to design thinking processes with an emphasis on formulating problems and understanding multiple point-of-views (concepts with multiple correct answers) (Huang et al., 2019). Figure 3 depicts an example of students' mastery of science concepts after learning the LCMR model. In contrast, Figure 4 illustrates an example of students' mastery of concepts after learning using the LC model. Those were examples of the answer to the question: "*Draw the shape of a leaf, its inner tissue, mitochondria, and their components.*"

Mastery of student concepts in the LCMR model group is complete and neater than the ones in the LC model group, as demonstrated in examples of student works shown in Figures 3 and 3. It can be seen from the ability of "ES" students to show the order of leaf organs starting from the macroscopic size, then microscopic, and symbolic, according to the order of the questions. The drawn macroscopic part was a complete leaf image. The microscopic part was the leaf mesophyll tissue consists of many types of cells, such as the epidermis, xylem, phloem, chloroplasts, spongy tissue, and stomata. Furthermore, the submicroscopic part was the mitochondrion, including its components such as DNA, matrix, crystals, granules, inner membrane, outer membrane, and ribosomes. The description of each organ part was clear and could be understood easily. The ability



Stomata terbuka respon terhadap deflesi CO2 di dalam rongga² udara
dan akibat fotosintesis sering penurunan konsentrasi CO2 pd siang hari
stomata akan tertutup secara progresif jika air dalam jumlah
yg cukup yang disalurkan ke daun.

Fig. 4: An answer of a student after learning using the LC model. It shows an illustration of a leaf, part of the leaf is taken and enlarged so that it shows the presence of leaf organelles such as stomata, H_2O, CO_2, and O_2 compounds (but the process that occurs was not explained). Then there are pictures of leaf mesophyll, including details on pole tissue, spongy tissue, stomata, guard cells, lower epidermis, xylem, and phloem. Furthermore, stomata, when close and open, includes details on cell walls, vacuoles, guard cells, and microfibrils.

to describe concepts macroscopically, microscopically and symbolically is an indicator of a person's mastery of concepts (Treagust & Tsui, 2013). At the same time, the example of the answer in the LC model showed pictures of leaves and their constituent parts that have not been neatly arranged. In addition, the descriptions of the pictures were not neatly organised and incomplete. Even so, they could draw and explain each component despite deviation from the command questions.

The difference in answers in Figures 3a and 2b shows that students had a slightly different mastery of concepts. Learning using the LCMR model contained training in compiling various representations, which indirectly increased students' mastery of concepts regarding plant physiology material. Each stage in compiling representations included meaningful activities which improved students' mastery (Fatmawati et al., 2023; Sutopo & Waldrip, 2014). The LCMR model allowed students to work collaboratively in small groups to conduct simple research, make reports, and conduct evaluations that facilitated students to develop ideas, apply existing knowledge and compile literature (Fatmawati et al., 2022).

The LCMR, which consists of LC and MR, is a constructivist learning model (Fatmawati et al., 2022; Ihejiamaizu et al., 2018). Students who followed the LC learning model were guided into a structured learning situation (Uyanık, 2016), so they had a good way of learning. Providing training in compiling representations in the LC model added learning experience (Sumarno et al., 2019). The concept of science helped students form other positive characteristics (A. Fatmawati et al., 2019), especially in plant physiology material rich with pictures, charts and graphs (Brunec et al., 2018; Sumarno et al., 2019). Therefore, the LCMR model successfully improved students' mastery of concepts in plant physiology.

The advantages of the LCMR model have also been proven by Sutopo et al., (2020). They demonstrated that the MR effectively improved students' mastery of science concepts. The results of other studies also show that MR positively enhanced mastery of science concepts (Tindani et al., 2021). Likewise, the LC composed with easy learning stages also contributed positively. Diyana et al. (2020) reported that LC 5E could also increase students' knowledge. Learning with MR integrated research, cognitive representational science, and constructivist education theory (Rau & Matthews, 2017). Considering those independent studies, it is thus justifiable that combining those models in the LCMR model could also improve students' mastery of concepts.

Mastery of the concepts in students' minds can be seen from single or multiple representations they arranged (Ainsworth, 2006). Lecturers could use the prepared representations to judge the level of students' understanding of a concept. The ability to explain demonstrated their level of understanding (Sutopo & Waldrip, 2014). MR supports the construction of thought when students connect the representations to identify a domain's shared features and properties.

CONCLUSION

The results showed that the LCMR model could increase the students' mastery of concepts in Plant Physiology material.

The ANCOVA analysis showed a significant difference (p-value of 0.00 < α) between the LCMR and the LC models used as the reference. This finding suggests the effectiveness of the learning models in enhancing the in-depth understanding of pre-service teachers in learning scientific concepts. The learning models can also be implemented in other biological concepts and scientific topics.

LIMITATION

This study contains limitations, most notably in the portion of the subject involving university students. There is still a need for further research on various areas, particularly for junior high and senior high school pupils. Additionally, this research is restricted to the examination of plant physiology. As a result, additional research is expected to examine other biological materials to form thorough findings.

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